User's Guide for the Human Exposure Model (HEM)

This user's guide should accompany The Human Exposure Model (HEM) User's Manual, 2002, Windows version

2002

Disclaimer

Introduction to HEM

The Human Exposure Model (HEM) is used primarily for major point sources (usually producers or large users of specified chemicals) of air pollutants on a nationwide basis. HEM only addresses the inhalation pathway of exposure. Each source in HEM must be specifically located by latitude and longitude. For each source, the release parameters must be described. These include stack height, exit velocity, emission rate, etc. The HEM provides annual average ambient concentrations, individual exposure, population exposure, for use with unit risk estimates and inhalation reference concentrations to produce estimates of cancer risk and noncancer hazard quotients. The model is designed to estimate population exposure to chemicals in the ambient air (i.e., air in the vicinity of an emitting source but beyond the sources's property boundary). The HEM estimates population exposure out to fifty kilometers from the source. The model is not to be used for estimating acute (peak short-term) exposures.

Brief description of HEM

The HEM produces quantitative estimates of potential human exposure to ambient air concentrations of pollutants emitted from stationary sources. The HEM contains (1) an atmospheric dispersion model, the Industrial Source Complex Model (Long-term) version 2, with included meteorological data, and (2) U.S. Bureau of Census population data at the census block level. The model utilizes 2000 census data. The input data needed to operate this model are source data (e.g., pollutant emission rates, plant location, height of the emission release, stack gas exit velocity, stack diameter, and temperature of the off-gases, pollutant properties and source location). Based on these inputs, the model estimates the magnitude and distribution of ambient air concentrations of pollutant in the vicinity of each source. The model usually estimates these concentrations within a radial distance of 50 kilometers (30.8 miles) from the source. Exposure in HEM is defined as people times concentration (micrograms per cubic meter annual average). This actually represents a surrogate for exposure as important exposure variables (e.g., duration, human mobility patterns, residential occupancy period, breathing rates, etc.) are not explicitly addressed. Multiple facilities, including clusters of plants, each having multiple emission points can be addressed by HEM.

The dispersion model within HEM is a Gaussian model (based on the Industrial Source Complex Long Term model, ISCLT2) that has been simplified to improve computational efficiency. The model utilizes a representative set of input values, e.g., meteorological data, as well as actual plant data (e.g., location, emission rate, stack height, etc.), and the concentrations input into the exposure algorithms are arrived at by interpolation to the centers of the census blocks. Specifying the latitude and longitude of the source automatically calls for data from the nearest meteorological station for use in the dispersion algorithm. The user may select another meteorological site if more representative. Stability array (STAR) summaries are the principal meteorological input to the HEM dispersion model. The STAR data are standard climatological frequency-of-occurrence summaries formulated for use in EPA models and are available for U.S. meteorological monitoring sites from the National Climatic Center, Asheville, North Carolina. A STAR summary is a joint frequency-of-occurrence of wind speed, atmospheric stability, and wind direction, classified according to Pasquill's stability categories. The STAR summaries in HEM reflect 5 years of meteorological data for each of 348 sites nationwide. The model produces a polar coordinate receptor grid, centered on each source, with receptors (grid points) at 10 downwind distances located along each of 16 radials which represent wind directions. Concentrations are estimated by the dispersion model for each of the 160 receptors on this grid. The 10 downwind distances for each radial are often 0.2, 0.5, 1.0, 2.0, 5.0, 10.0, 20.0, 30.0, 40.0, and 50.0 kilometers. The center of the receptor grid for each plant is assumed to be the plant center.

The HEM uses the estimated ground level concentrations of a pollutant together with population data to estimate exposure. For each of the 160 receptors located around a source, the concentration of the pollutant and the number of people estimated by the model to be exposed to that particular concentration are identified. The HEM multiplies these numbers together to produce exposure estimates and sums these products for each census block impacted by each source. All people residing in a census block are assumed to be located at the center of the block and therefore all are assumed to be exposed to the concentration that is logarithmically interpolated radially and arithmetically interpolated azimuthally from the four receptors of the polar coordinate grid system that bound the census block center. As stated above, unless otherwise specified, a calculation of concentration is made for each census block within 50 kilometers of the source's location. If a census block is exposed to more than one source, the impacts from each source are summed for each census block.

Input data

As mentioned above, the meteorological data and the population data are part of the HEM computer data base. The necessary input data falls into four categories:

1. Source location
2. Emissions data
3. Vent parameter data
4. Pollutant specific data (reactivity and dose-response data)

Source location, emission data, and vent parameter data are always necessary to analyze sources. The atmospheric reactivities, however, are only necessary when the chemical is extremely reactive. For example, the atmospheric half-life should be specified for those chemicals with half-lives of less than two or three hours. The following section provides additional guidance on the information needed and possible sources of the information as well as how to input the data into a file for use by the program.

To estimate cancer risks and hazard quotients from the computed exposure estimates, the cancer potency estimate or unit risk estimate (URE) and inhalation reference concentration (RfC) must also be included for the pollutant being modeled . (These are generally obtained from EPA's National Air Toxics Assessment (NATA), at www.epa.gov/ttn/nata). The URE is the estimated probability of a person contracting cancer as a result of constant exposure to an ambient concentration of 1 ug/m3 over their lifetime. These values are generally the 95% upper confidence limits on risk; the actual cancer risks are not likely to be higher and may be lower including zero risk. The RfC is defined as an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) to an annual average concentration of a compound that is likely to be without an appreciable risk of deleterious effects during a lifetime.

Many sources emit more than one compound. HEM models one hazardous air pollutant (HAP) for each run of the model. To model multiple chemicals, the modeler can choose between two options. The first option is toxicity weighting of each HAP by multiplying the emission rate of a HAP by its URE for carcinogens and for chronic non-carcinogens divide the emission rate by its RfC. The potency entered in the HEM input file for both carcinogen and chronic non-carcinogens is 1.0. This is done for all emitted HAP and if the results show that one compound dominates by a large amount, the modeler can model this one HAP.

The second and more commonly used option, involves converting emissions of potential carcinogens into, for example, benzene equivalent emission rates. For each potential carcinogen, multiply that HAP's emission rate by its URE, as above, but also divide by the URE for benzene. This is summed for all carcinogenic HAP emitted from each emission source at each source. The process is similar for compounds believed to cause chronic non-cancer adverse health effects (hazard index). However, for carcinogens, the higher the URE the more potent is the HAP. For chronic non-cancer effects, the higher the RfC the less potent the HAP. Thus to convert emissions of multiple chronic non-cancer HAPs to a toxic weighted emission rate, toluene for example, divide the toluene RfC by that HAPs RfC and multiply the resulst by that HAPs emission rate These are summed for all chronic non-cancer compounds emitted from the source. In addition, the RfC's are reported in milligrams per cubic meter of air. Although the resulting ratio is the same whether it is based on milligrams or micrograms, the RfC in micrograms per cubic meter of air must be input to HEM. Simply multiply by 1000 to convert milligrams to micrograms. In addition, due to the differences in the way HEM handles HAPs with UREs and those having RfCs, HEM is run separately for potential carcinogens and run again for chronic non-cancer effects. The potency value that is entered in the HEM input file for carcinogens is, for this example, the benzene URE. For chronic non-carcinogens the value entered in the potency field is the reciprocal of the toluene RfC.

Source location

The geographical location (latitude and longitude) of the source being simulated must be identified in order to run HEM. Specific point source locations may be acquired from a variety of published references. These include:

1. State approved emission permits
2. EPA's Toxic Release Inventory (www.epa.gov/enviro/html/tris/)
3. Existing EPA exposure and risk reports
4. Industry trade association reports
5. EPA's National Emission Inventory (www.epa.gov/air/data/index
6. United States Geologic Survey Maps (USGS)

(http://mapping.usgs.gov/partners/viewonline/html)

In addition, if the street address, city, state, and ZIP code information are known, commercially available, affordable, software is available to convert this information into latitude and longitude coordinates. One such product is Street Atlas, USA by DeLorme. Some of the above sources of geographic information may provide coordinates in Universal Transverse Mercator (UTM) units. The HEM also contains a program to convert UTM data into latitude and longitude. The program is named utm_calc and is a DOS program. To use the HEM version the file is found at C:\HEM\HEM\SRC\UTM_CALC\MSC.PLT. Open this file and from the list of options hit Control U from the keyboard. Enter the UTM Easting in the field provided. This field is 5 characters long, thus 325.7 for example, is input. Hit the enter key and input the UTM Northing value in the space provided. This field is 6 characters long including the decimal point (for example input 4321.9). Next enter the 2 digit UTM Zone (for example 17). The program converts the UTM coordinates into decimal degrees latitude and longitude, latitude and longitude in degrees, minutes and seconds, and also repeats the UTM coordinates that were entered.

Emissions data

The total emissions resulting from the production of a chemical or intermediate use of a specific chemical are, in general, a summation of process, storage, and fugitive emissions losses. Process emissions are discrete losses that occur at stacks or process vents from reactors, columns, boilers, and other types of plant equipment. Storage emissions include losses from the raw material feed, in-process and final process storage tanks, as well as from loading and handling losses. Fugitive emissions are losses that result from plant equipment leaks, evaporation from waste products and other non-discrete sources. Emissions information can be obtained from the following sources at the web sites listed above:

1. Toxics Release Inventory
2. National Emissions Inventory
3. State and Federal risk assessment reports
4. Background Information Documents that support Maximum Achievable Control Technology Standards (MACT) (available from EPA MACT docket)
5. State approved emission permits

Once the emissions data for each emission source and each pollutant is obtained they must be converted to kilograms per year to input into HEM.

Vent parameter data

Vent parameter data are necessary for dispersion modeling of the chemical emissions. Vent parameter data include stack and vent height in meters, stack or vent diameter in meters, gas discharge temperature in degrees Kelvin, gas emission (exit) velocity, and if appropriate, building cross-sectional area in square meters. If sources of fugitive emissions are present, the area of the fugitive discharge in square meters is needed. These data can often be found in the same data sources as the emissions data.

Atmospheric reactivities of chemicals

A variety of studies have reported the lifetime or atmospheric residence time of many potentially hazardous air pollutants. Often, however, the basis for the decay rates are not given and reconciliation between studies is difficult. Thus, since these values tend to be uncertain, we recommend examining all available data and using engineering judgment to select the appropriate value.. One source of information for some compounds is the web site for environmental data bases at http://esc.syrres.com/efdb.htm. Another is a the EPA document "Fate of Toxic and Hazardous Materials in the Air Environment" 1980, L.T. Cupitt, EPA-600/S3-80-084 found in Appendix Aof this report.

The HEM is generally limited to a study area within a fifty kilometer radius of the source. In most instances, the reactivity of a chemical is not sufficiently high to cause significant removal before the material is dispersed to this distance. Therefore, in many cases this input to the HEM can be left blank to assume no atmospheric decay without causing a loss in accuracy. Some chemicals, however do have high reactivity (e.g., formaldehyde, 1,3-butadiene) and should be analyzed for this behavior. Atmospheric degradation in HEM is limited to a first order approximation. In a user specified file, the reciprocal of the daylight half-life, in minutes, is placed in row one, columns 1 to 10, and the reciprocal of the night-time half-life, in minutes, is placed in columns 11 to 20 also in row one. The file must be selected from the HEM run stream menu before running HEM.

Dispersion modeling

The previous section discussed the information necessary to run HEM. This section explains how those data are used to give the resulting exposure estimates.

The concentration patterns produced by major point sources emissions depend heavily on a number of factors. These include:

1. Emission rate
2. Physical stack height and effective plume rise
3. Wind speed and direction
4. Dispersive effects or intensity of atmospheric turbulence
5. How population is distributed around the source

The dispersion model in HEM is the Industrial Source Complex Long-Term version 2 (ISCLT2) (EPA-450/4-88-002a 1987). Flat terrain is assumed. In many instances there is more than one type of emission source (each with its characteristic release height, emissions rate, etc.) within a single plant. Each emission source is modeled individually, and the total ground level concentrations resulting from plant emissions are then computed by summing the individual estimates. There are two options, depending upon data availability, for locating emission sources on plant property. The default option is that all emission sources will be located at the specified latitude and longitude of the center of the plant. If location coordinate data are available for each emission source, then each emission source should be modeled individually, using single counting of population (to be discussed later). The aggregate exposure from all source emissions are shown in the next to the last table of HEM outputs (to be discussed later).

Chemical reactivity

Chloroprene is used as an example to illustrate the effect of chemical reactions on ambient concentrations. Chloroprene is an organic compound that is decidedly photoreactive in the atmosphere. Based on preliminary calculations conducted with the estimated chloroprene atmospheric decay rate, approximately 90 percent of the chloroprene emitted into the sunlit urban atmosphere would be removed within an hour through reaction with hydroxyl radicals and ozone. However, the chemical decay rates are much lower in the nighttime or under overcast conditions. Figure 1 displays a comparison between the resulting annual average concentrations along a single wind direction with and without the chemical decay computed. Because the atmospheric reactions change atmospheric concentrations over time, the reactivity of a compound has less impact on the concentrations near the emissions source than farther downwind. The difference in concentrations between the two curves at 20 meters from the source is about 3 percent: at 20 km from the source the difference is about 30 percent.

Building wake effect

Pollutants emitted into the wake of a building are subject to an enhanced dispersion (i.e., the concentration is reduced very quickly by the turbulence on the lee side of the building). The ground level concentrations that result from different building structure dimensions are depicted in Figure 1, where the major parameters for estimating these concentrations are the same as those listed above with the exception that the building cross sectional area must also be input. To estimate the building wake effect, the largest building cross sectional area from any wind directions is used. The building wake effect has insignificant impacts on ground-level concentrations at points further downwind from the source than 1.0 km. However, sources with larger building effects would result in larger ground level concentrations near the source.

Population exposure estimation

The dispersion modeling approach is coded in a standard Fortran program. The output of the program is a concentration array for 160 receptors around the plant (10 receptors along each

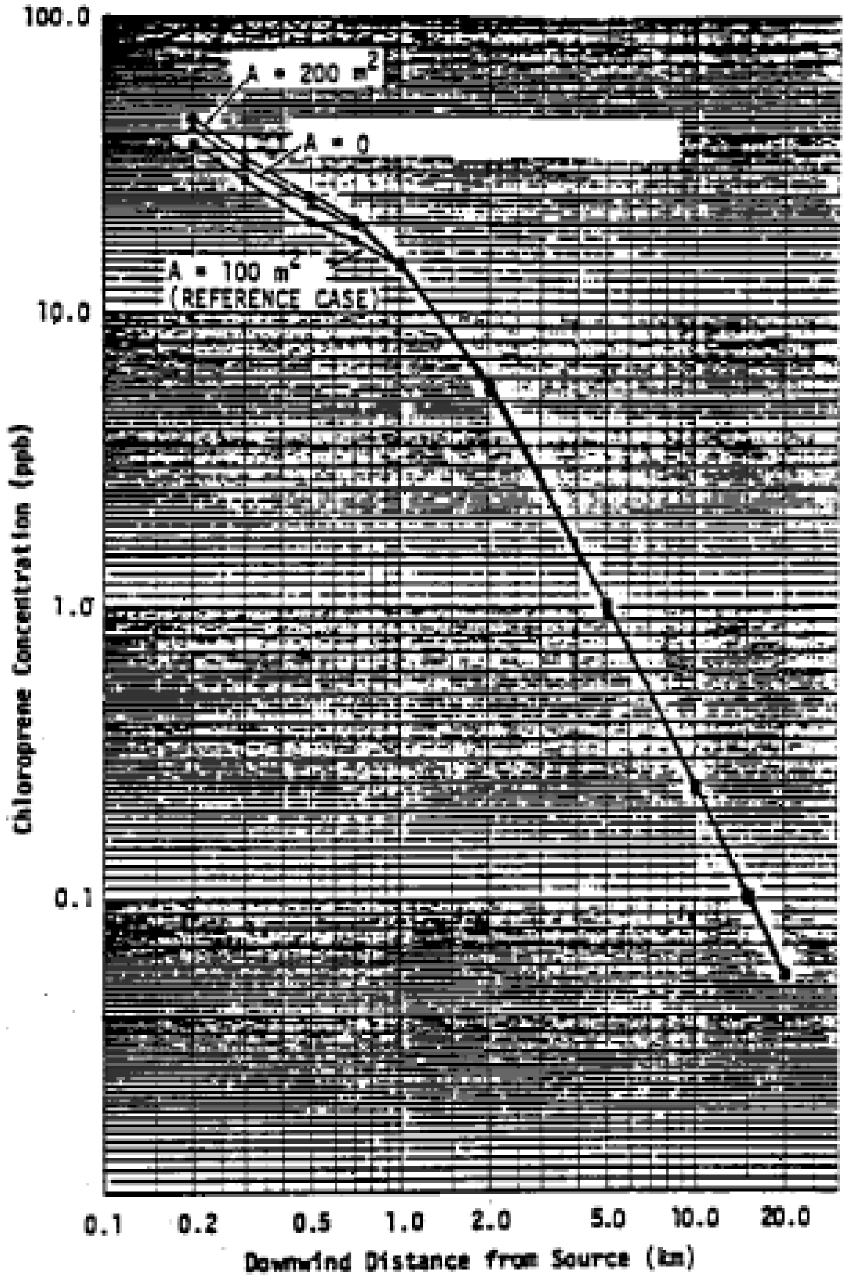


Figure 1 - Effects of Building Wake on Concentration Distribution of Chloroprene

of the 16 wind directions). These are the sum of the concentration patterns resulting from all sources within a plant. This section outlines the basic approach used in combining the concentration pattern with the population distribution pattern around a plant.

Population exposure is estimated as the product of the population and the concentration to which that population is exposed. To form this product, both the concentration and the population must be known at the same location. This calculation of population exposure ignores

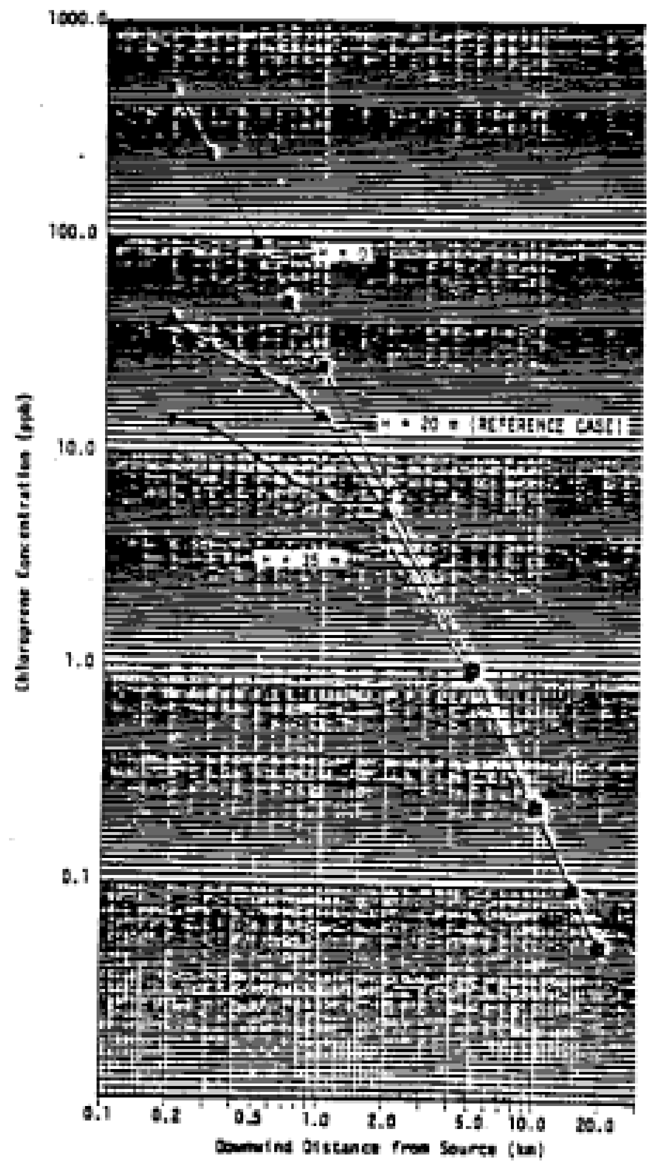


Figure 2 - Impacts of release height on concentration distribution of Chloroprene

population mobility, exposure duration, breathing rates, and other factors that are important in quantifying exposure. The HEM calculated population exposure is best thought of as a surrogate for exposure or a simple approximation of exposure which can be subsequently refined if more detailed information are available.

Log-log linear interpolation is used to estimate the concentration at each census block population centroid. The population centroid is the area weighted center of a census block. On average, a census block contains forty people although the range can be rather large (ranging from one person to several thousand). Concentration estimates for 160 receptors, the intersection of the 10 ring distances and 16 wind directions, are estimated for each source. Each census block centroid is surrounded by four receptors which are located at the four corners of the polar sector (also called a grid cell), the area bounded by two wind directions and two radial arcs. These four receptors, labeled C1, C2, C3,and C4, surround the centroid, labeled Cx as depicted in Figure 3. As shown in Figures 1, and 2, there is generally a linear relationship between the logarithm of concentrations and the logarithm of distances. This relationship is used to estimate the concentrations at points CA1 and CA2 (see Figure 3). These estimates are then linearly interpolated with the polar angle to determine the concentration at the centroid (Cx). This process is repeated for each centroid within 50 km of each source.

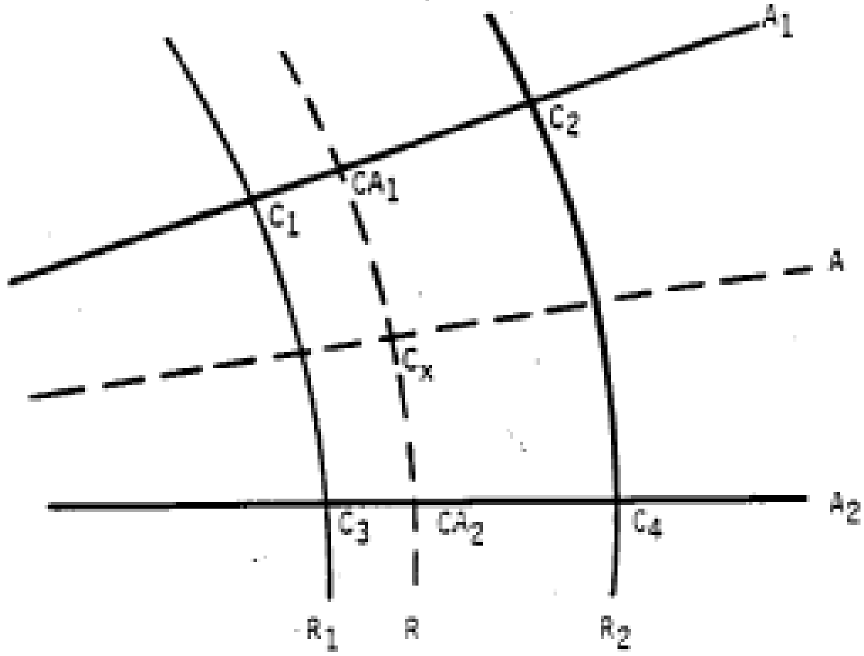
Total exposure is then computed as the sum of the population times interpolated concentrations for all census blocks within 50 km of the source. The exposure of the fraction of the population that is exposed to concentrations greater than or equal to each of a number of concentration levels or "bins" is estimated. These bins are automatically selected by the program. For example, the bins descending from a bin of 1.0 ug/m3 or greater are 0.5 ug/m3, 0.25 ug/m3, 0.1ug/m3, 0.05 ug/m3, 0.025 ug/m3, 0.01 ug/m3 and so on.

Uncertainties

In addition to model uncertainty and uncertainties associated with emissions, emission point locations and release characteristics, the following sections address uncertainties related to exposure models such as HEM. In order for HEM to run quickly and require minimal input data, certain assumptions were made. For example, the model uses census data to the census block level. Although this is the smallest defined population unit, it still places, on average, about 40 people at one point, the area-weighted center of the census block. In reality, some people may reside closer to the emission source and may be more highly exposed than the model estimates, while others may be farther away and subject to lower exposures than the model estimates.

The concentration patterns used in the exposure computations are obtained through atmospheric dispersion modeling based on known source characteristics and weather patterns at nearby weather stations. Naturally, any deviations in weather pattern estimates from the true pattern can directly affect the exposure results. Thus, if the nearest weather station is 50 - 100 miles away, the weather patterns may not be representative of the weather patterns in the area around the source.

The program also assumes flat terrain. In most cases, this assumption does not result in erroneous results. However this factor may be more critical when dealing with tall release sources in a valley or mountainous area. In these situations, the weather station data may not give adequate information to model the wind patterns accurately, and the model may underestimate actual impacts and risks for nearby elevated terrain.



Given:

A = The angle in degrees subtended clockwise about the source from due south to the BG/ED centroid;

A_1 = The angle from due south to the radial line immediately counterclockwise from A, or passing through A if there is an exact match;

A_2 = The angle from the south to the radial line immediately clockwise of A_1 (A_2 is 0 if it is due south);

R = The distance from the source to the BG/ED centroid;

R_1 = The distance from the source to the largest circular arc of radius on grid that is less than R;

R_2 = The distance from the source to the smallest circular arc of radius on grid that is greater than or equal to R;

C_1 = The concentration value at (A_1, R_1);

C_2 = The concentration value at (A_1, R_2);

C_3 = The concentration value at (A_2, R_1);

C_4 = The concentration value at (A_2, R_2); then

$CA_1 = \exp(\ln C_1 + (\ln C_2 - \ln C_1)(\ln R - \ln R_1) / (\ln R_2 - \ln R_1)$

$CA_2 = \exp(\ln C_3 + (\ln C_4 - \ln C_3)(\ln R - \ln R_1) / (\ln R_2 - \ln R_1)$

$C_x = CA_1 + (CA_2 - CA_1)(A - A_1) / (A_2 - A_1)$

Figure 3 - Log Linear Interpolation Scheme

In addition, the HEM uses a Gaussian dispersion model that is based on how gases will act when dispersed from a stack. Thus, if the pollutant is fibrous or particulate, such as asbestos, the assumption that the pollutant behaves as a gas may misrepresent the actual dispersion pattern. The assumption is also made that the annual average weather conditions continually persist and that the source emits constantly at the annual average amount. At times, these averages may not be representative over shorter terms. It also assumes that each recorded wind persists in a given direction long enough to yield dispersion out to 50 km.

There are also time-dependent aspects of the exposure problem. The exposure program uses a time-averaged concentration pattern for each source, so that the time dimension is ignored in the computations. If the population distribution were essentially constant over the averaging time period, the resulting estimates would be true averages. However, population distributions are constantly changing as people commute to work, go shopping, and take longer trips. Particularly in urban industrial centers, the shifts in populations and concentrations throughout the day may be highly correlated; thus, the actual exposure may differ considerably from the value obtained by matching time-averaged concentrations with population distributions based on census addresses. Whether the exposure is over- or underestimated depends on whether populations in the vicinity of a source are drained (e.g., because people leave residences near the source for work in an urban center) or are augmented (e.g., because of employment near the source).

Although several simplifications and assumptions are made in HEM, the model can provide rather accurate representations of maximum individual impacts and population exposures given correct input data and that developing more refined estimates is often more resource intensive (in terms of gathering necessary data) than the resulting increases in accuracy would justify.

Output from HEM

HEM output includes the cumulative risk summary and the overall source summary. Also, concentration grid tables and maps of census block population centroids may be generated if this option was selected.

An example of the cumulative summary is shown in Figure 4. This table starts at the highest concentration to which an individual is exposed. It then reports how many people are predicted to be exposed to that concentration and the resulting exposure (concentration times population). The next level is a certain increment lower concentration (about ½ of the previous concentration) with the number of people exposed to that concentration or higher. The exposure in this instance is the cumulative exposure from the level 2 concentration and those higher. The following levels are similarly calculated until the concentration level reaches the minimum predicted within the 50 Km polar grid.

An example of the overall source summary is shown in Figure 5. As indicated by the label in the column on the upper far right of the table, three such summaries are usually produced. The first is ordered according to the order of the input data file which is shown in Figure 5. The second is ordered highest to lowest by the maximum individual lifetime risk number. The third is ordered highest to lowest by the annual incidence.

The first half of the overall source summary, the first five columns from the left, deals with the risk associate with the maximum offsite concentration, and as such is labeled "MAXIMUM" in the table. The first column reports the maximum concentration to which a person is predicted to be exposed. The second column reports the number of people predicted to be exposed to that concentration. The third column reports the population exposure (people x concentration) associated with that concentration. The fourth column reports the predicted lifetime incidence (exposure x unit risk) associate with the maximum concentration. The fifth column is the maximum individual risk and is calculated by multiplying the maximum concentration by the unit risk number.

The next part of the summary, labeled "MINIMUM"and includes columns six through ten, deals with the minimum and overall concentrations and exposures. The first column of this half (the sixth column from the left) reports the minimum predicted concentration within 50Km of the source. The next column reports the total number of people predicted to be exposed to any concentration of the chemical within 50Km of the source. The next column reports the cumulative exposure for all census blocks within 50Km of the source. The next column reports annual incidence and is calculated by multiplying the cumulative exposure by the unit risk number which yields lifetime risk and dividing by seventy (the estimated life span) to yield an average annual incidence. The next column, labeled "repeat interval", is simply the inverse of the annual incidence column. This is used to describe how many years elapse before one case of cancer is predicted to occur. The last column reports the source name.

Figure 4. Cumulative Summary

Summary for Iron and Steel
Maximum Radius = 50.0 KM

Level	Concentration	Population	Exposure
1	1.64E-03	7	1.19E-02
2	1.003-03	32	4.24E-02
3	5.00E-04	422	3.17E-01
4	2.50E-04	7,230	2.72E+00
5	1.00E-04	66,700	1.10E+01
6	5.00E-05	240,000	2.27E+01
7	2.50E-05	733,000	3.95E+01
8	1.00E-05	2,810,000	7.00E+01
9	5.00E-06	8,000,000	1.04E+02
10	2.50E-06	22,500,000	1.57E+02
11	1.00E-06	28,000,000	1.67E+02
12	5.00E-07	31,500,000	1.69E+02
13	2.50E-07	33,500.000	1.70E+02
14	1.00E-07	33,600.000	1.70E+02
15	5.00E-08	33,600,000	1.70E+02
16	4.61E-08	33,600,000	1.70E+02

Figure 5. Overall Summary Chart

Summary For Iron And Steel   Sorted by input order
With a Unit Risk of 2.30E-03

MAXIMUM					MINIMUM					
Conc	People	Exposure	Incidence	Max Risk	Conc	People	Exposure	Annual Incidence	Repeat Interval	Source
2.63E-04	605	1.59E-01	3.66E-04	6.06E-07	1.65E-07	1,270,000	1.53E+01	0.0005	2,000.	Source 1
7.41E-05	399	2.96E-02	6.80E-05	1.70E-07	4.61E-08	1,270,000	5.98E+00	0.0002	5,100.	Source 2
2.89E-04	1	1.69E-04	3.88E-07	6.65E-07	9.35E-07	1,140.000	5.71E+00	0.0002	5,300.	Source 3
4.37E-04	20	8.63E-03	1.99E-05	2.99E-06	2.99E-07	237,000	1.03E+00	<0.0001	30,000.	Source 4
1.19E-04	25	2.98E-03	6.84E-06	2.74E-07	4.99E-07	8,000,000	3.42E+01	0.0011	890.	Source 5
1.64E-03	7	1.19E-02	2.78E-05	3.78E-06	6.91E-07	904,000	1.94E+01	0.0006	1.600.	Source 6
1.19E-04	50	5.96E-03	1.37E-05	2.74E-07	5.43E-07	10,800,000	4.95E+01	0.0016	620.	Source 7
2.01E-04	59	1.20E-02	2.75E-05	4.63E-07	1.89E-07	739,000	2.30E+00	0.0001	13,000.	Source 8
2.37E-04	7	1.74E-03	4.00E-06	5.45E-07	1.92E-07	707,000	5.91E+00	0.0002	5,100.	Source 9
2.18E-04	91	1.98E-02	4.54E-05	5.02E-07	1.49E-07	1,240,000	1.81E+00	0.0001	17,000.	Source 10
6.88E-05	4	2.82E-04	6.48E-07	1.58E-07	2.89E-07	4,530,000	4.76E+00	0.0002	6,400.	Source 11
1.15E-03	4	4.20E-03	9.67E-06	2.64E-06	9.91E-07	2,750,000	2.43E+01	0.0008	1,300.	Source 12

An example of the concentration grid table, as shown in Figure 6, presents the modeled concentration at each grid point. For example, the figure shows that the concentration 1.00 kilometers south of the plant is predicted to be 8.8588 X 10-6 g/m^3. The column labeled wind direction is the upwind direction from the plant, not the direction the wind is blowing.

The four optional maps show the population distribution about the source as a polar grid displayed rectangularly. The four plots differ in the orientation of their grids relative to the input concentration grid. Again, direction refers to actual direction from the plant, not wind direction.

An example of the first plot, seen in Figure 7, shows both the number of census block centroids and the number of people in each cell of the concentration grid. The labels of the wind directions refer to the line directly above them and the radius label refers to the line directly to the right. For example, the table shows at 2 km to the Northeast of the source one census block centroid with 577 people. This should be understood to mean that one census block centroid with 577 is located between 1 km and 2 km to the Northeast of the source. The second plot helps to somewhat more accurately located the census block centroid.

(CONCENTRATION (MICRO GRAMS/CUBIC METER))

WIND DIRECTION	DOWNWIND DISTANCE (KM) .200	.500	1.000	2.000	5.000	10.000	20.000	30.000	40.000	50.000
S	3.1240-007	4.8022-006	8.8508-006	7.7022-006	5.0673-006	2.6651-006	1.2593-006	8.1918-007	6.0946-007	4.8641-007
SSW	2.3631-006	2.8354-005	4.7424-005	3.6502-005	1.6587-005	7.0601-006	3.6893-006	2.3653-006	1.7217-006	1.3430-006
SW	9.2678-007	1.2501-005	2.1710-005	1.6840-005	7.7781-006	4.0595-006	2.1311-006	1.4487-006	1.0995-006	8.8675-007
WSW	1.3930-006	1.7671-005	3.0300-005	2.3339-005	1.0221-005	5.4012-006	3.0744-006	2.1707-006	1.6845-006	1.3773-006
W	1.6492-007	2.3099-006	4.2179-006	3.6072-006	2.1037-006	1.3779-006	8.8997-007	6.9326-007	5.8401-007	5.1045-007
WNW	4.5832-007	5.1345-006	8.8190-006	7.0336-006	3.5560-006	2.0301-006	1.1900-006	8.9060-007	7.3241-007	6.2978-007
NW	4.6912-007	4.4500-006	7.6494-006	6.1773-006	3.2511-006	1.9040-006	1.1445-006	8.7824-007	7.3842-007	6.4634-007
NNW	7.4781-006	5.0217-005	8.0205-005	5.0567-005	2.2946-005	1.0104-005	4.6058-006	2.9705-006	2.2163-006	1.7827-006
N	6.1570-006	4.8889-005	7.9423-005	5.6579-005	2.3518-005	1.0830-005	5.1378-006	3.3863-006	2.5606-006	2.0769-006
NNE	1.6300-005	1.5788-004	2.6054-004	1.9243-004	7.5911-005	3.4863-005	1.6567-005	1.0755-005	7.9056-006	6.2173-006
NE	3.4906-006	3.5345-005	5.8425-005	4.3456-005	1.7846-005	8.3118-006	3.9381-006	2.5548-006	1.8827-006	1.4862-006
ENE	1.9528-005	1.6507-004	2.6330-004	1.9224-004	7.5487-005	3.2475-005	1.3046-005	8.3712-006	5.8425-006	4.4137-006
E	2.4914-006	2.2872-005	3.7148-005	2.7945-005	1.2083-005	5.4017-006	2.3581-006	1.4417-006	1.0223-006	7.8501-007
ESE	1.2367-005	1.1828-004	1.9415-004	1.4408-004	5.9437-005	2.5948-005	1.1104-005	6.7265-006	4.7003-006	3.5531-006
SE	1.1515-006	1.4731-005	2.5381-005	1.9845-005	9.4195-006	4.5800-006	2.1831-006	1.4088-006	1.0299-006	8.0629-007
SSE	1.2144-006	1.8820-005	3.3463-005	2.7572-005	1.5341-005	7.6519-006	3.6334-006	2.3557-006	1.7323-006	1.3631-006

Figure 4 - Individual Plant Concentration Grid

An example of the second plot, seen in Figure 8, gives the same type of plot as the first except that the spaces shown are patches rather than grid cells. Patches are defined by the midpoint between cell radii and the midpoint between wind directions. These patches form an area surrounding a receptor site rather than each corner being a receptor site as in the case of the grid cell. To carry the example in the preceding paragraph one step further, Figure 8 now gives the location of the census block centroid as 577 people located at 1 km. This should be understood to mean that this centroid can be found between 1.0 to 1.5 km to from the source. Figure 7 located the centroid between 1km and 2 km; Figure 8 tells us that it is closer to 1km than 2 km, but farther out than 1 km.

The last two plots, not shown here, are versions of the first plot, with each input grid subdivided into quadrants. For each quadrant, the number of census block centroids (third plot) or the population (fourth plot) is shown.

MAP OF POPULATION BY CONCENTRATION RADIUS

CONCENTRATIONS ARE IN UNITS OF MICRO-GRAMS PER CUBIC METER
ASARCO EL PASO, TX

DIR	RADIUS	.200	.500	1.000	2.000	5.000	10.000	20.000	30.000	40.000	50.000
S	# CNTRDS	0	0	0	0	0	0	0	0	0	0
	POP	0	0	0	0	0	0	0	0	0	0
SSW	# CNTRDS	0	0	0	0	0	0	0	0	0	0
	POP	0	0	0	0	0	0	0	0	0	0
SW	# CNTRDS	0	0	0	0	0	0	0	0	0	0
	POP	0	0	0	0	0	0	0	0	0	0
WSW	# CNTRDS	0	0	0	0	0	0	0	0	0	0
	POP	0	0	0	0	0	0	0	0	0	0
W	# CNTRDS	0	0	0	0	0	1	0	1	0	0
	POP	0	0	0	0	0	3377	0	405	0	0
WNW	# CNTRDS	0	0	0	0	1	5	2	1	0	0
	POP	0	0	0	0	932	6037	230	661	0	0
NW	# CNTRDS	0	0	0	0	0	6	13	1	3	2
	POP	0	0	0	0	0	13442	8210	774	1966	1201
NNW	# CNTRDS	0	0	2	0	1	4	2	7	3	3
	POP	0	0	610	0	375	11535	1071	4300	1998	3390
N	# CNTRDS	0	0	0	0	0	0	1	2	0	1
	POP	0	0	0	0	0	0	2	1417	0	0
NNE	# CNTRDS	0	0	0	0	4	3	33	4	1	1
	POP	0	0	0	0	10738	5691	55117	765	205	0
NE	# CNTRDS	0	0	0	1	1	18	20	1	0	0
	POP	0	0	0	577	1727	16771	37217	0	0	0
ENE	# CNTRDS	0	0	0	0	2	29	16	1	0	1
	POP	0	0	0	0	3175	28857	29872	1600	0	0
E	# CNTRDS	0	0	0	1	9	43	62	8	3	0
	POP	0	0	0	2347	8007	33481	103274	10226	1956	0
ESE	# CNTRDS	0	0	0	0	22	11	9	31	4	4
	POP	0	0	0	0	15861	5410	19035	31877	3709	2498
SE	# CNTRDS	0	0	0	0	2	1	0	0	0	0
	POP	0	0	0	0	1259	266	0	0	0	0
SSE	# CNTRDS	0	0	0	0	0	0	0	0	0	0
	POP	0	0	0	0	0	0	0	0	0	0

MAP OF POPULATION BY PATCH   RADIUS

CONCENTRATIONS ARE IN UNITS OF MICRO-GRAMS PER CUBIC METER
ASARCO EL PASO, TX

DIR	RADIUS	.200	.500	1.000	2.000	5.000	10.000	20.000	30.000	40.000	50.000
S	# CHIRDS	0	0	0	0	0	0	0	0	0	0
	POP	0	0	0	0	0	0	0	0	0	0
SSW	# CHIRDS	0	0	0	0	0	0	0	0	0	0
	POP	0	0	0	0	0	0	0	0	0	0
SW	# CHIRDS	0	0	0	0	0	0	0	0	0	0
	POP	0	0	0	0	0	0	0	0	0	0
WSW	# CHIRDS	0	0	0	0	0	0	0	0	0	0
	POP	0	0	0	0	0	0	0	0	0	0
W	# CHIRDS	0	0	0	0	0	0	0	0	0	0
	POP	0	0	0	0	0	0	0	0	0	0
WNW	# CHIRDS	0	0	0	0	1	0	0	1	0	0
	POP	0	0	0	0	3377	0	0	405	0	0
NW	# CHIRDS	0	0	0	0	5	9	2	1	0	0
	POP	0	0	0	0	5834	10160	808	1083	0	0
NNW	# CHIRDS	0	0	2	0	5	7	9	4	4	3
	POP	0	0	818	0	9815	3428	8369	2294	3673	2812
N	# CHIRDS	0	0	0	0	3	0	2	1	0	1
	POP	0	0	0	0	8593	0	2	69	0	0
NNE	# CHIRDS	0	0	0	2	0	1	13	4	0	1
	POP	0	0	0	5803	0	0	17270	1879	0	0
NE	# CHIRDS	0	0	1	0	5	32	14	1	0	0
	POP	0	0	577	0	5881	43857	26965	330	0	0
ENE	# CHIRDS	0	0	0	2	10	17	1	0	0	1
	POP	0	0	0	3028	12956	25062	0	0	0	0
E	# CHIRDS	0	0	0	2	30	41	30	0	0	0
	POP	0	0	0	1588	23547	42987	65461	0	0	0
ESE	# CHIRDS	0	0	0	6	22	10	45	15	1	0
	POP	0	0	0	5667	18926	21122	74422	8514	482	0
SE	# CHIRDS	0	0	0	5	16	0	0	9	3	2
	POP	0	0	0	5274	8745	0	0	7164	2511	362
SSE	# CHIRDS	0	0	0	0	0	0	0	0	0	0
	POP	0	0	0	0	0	0	0	0	0	0